EVALUATION OF PRIMARY PROCESSING TECHNIQUES ON LOCAL CASSAVA FLOUR PRODUCTION USING THE PEDAL-OPERATED HAMMER MILL

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ABSTRACT

Processing of cassava root chips into flour under local conditions can be considered as the most favorable technique in terms of production rate, flour recovery, and processing cost. On the other hand, the technique which involved the pressing of grated roots prior to drying resulted in great loss of free starch; higher labor cost for grating, pressing, and milling; and a slow flour production process. Generally, chips can be processed into refined flour at the rate of 4.41 to 4.83 kg/hr using the pedal-operated hammer mill. Essential flour recovery is placed at 25 to 29% and the process costs only ₱1.04 to ₱1.17 per kg. On the other hand, rasped roots or grates can be processed into refined flour at the rate of 2.82 to 2.98 kg/hr with flour recovery of 9 to 11% and processing cost of ₱1.58 to ₱1.70 per kg.

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KEY WORDS: Cassava *(Manihot esculenta).* Chips. Grates. Local flour production. Pedal-operated hammer mill.

INTRODUCTION

In the bread-making industry, partial substitution of wheat flour with cassava flour has been established. Cassava flour mixtures are accepted at 10 to 20% substitution levels for *pan de sal* and sandwich breads, 50% for cakes and doughnuts, and up to 100% for cookies and biscuits (Agrix, 1975).

Flour production is simple and viable as a cottage industry. It requires only two size-reduction equipment — the chipper/rasper and the flour mill. Manual labor is easily available in the farm and can thus be efficiently employed to operate these labor-saving devices. Some prototypes of these devices have already been developed at the Philippine Root Crop Research and Training Center (PRCRTC) in ViSCA.

Flour processing techniques at farm level vary depending on the place and the tradition of the people. Kay (1973) reported that in India and some parts of Eastern Africa, the peeled tubers are usually sliced and dried under the sun to produce chips which are often ground into flour. In most Muslim areas in the Philippines where cassava is the staple food, the roots are pulped by rasping. The pulps are pressed to extract free starch and water prior to drying. The dried pulps are then ground into flour.

Flour mills are either of the hammer or the attrition type (Henderson and Perry, 1976). Sieve screens are used to produce the desired sizes of the products (flour grades). According to an Agrix manual (1975), ground cassava chips should pass through mesh number 120 sieve to obtain high grade flour. However, mesh number 60 sieve can also be used to separate fine flour from coarse flour. The latter is reported to be more acceptable for bread making than the former (Grace, 1977).

Widely practised primary processing techniques have been identified and these fall into four distinct groups: chipping and washing, chipping without washing, grating and pressing, and grating without pressing. The effects of each technique on labor input, drying time, milling output, and flour production rate are not yet known. It was earlier reported that chipping without washing resulted in clean and lustrous dried products while hand-pressing the grates resulted in shorter drying time. This study thus evaluated these primary techniques on farm level cassava flour production.

MATERIALS AND METHODS

Chip Preparation

Six kilograms of cassava (cv. Golden Yellow) roots were peeled, washed and then chipped using the PRCRTC pedal chipper/grater. Half of the fresh chips was further washed to remove the fine pulps and adhering soluble starch while the remaining half was not washed again. These served as the washed and unwashed treatments with three replications each. The whole process is shown in Figure 1.

Grate Preparation

Another six kilograms of clean cassava (cv. Golden Yellow) roots were grated using the same pedal chipper/grater. Half of the grates was manually pressed using the PRCRTC mechanical presser to extract adhering starch and part of its water. Unpressed grates were also prepared separately. Three replications were made for each treatment.

Determination of Drying Characteristics

The initial moisture contents on wet basis (M.C.w.b.) of the four treatments (unwashed chips, washed chips, unpressed grates and pressed grates) were determined using the following equation:

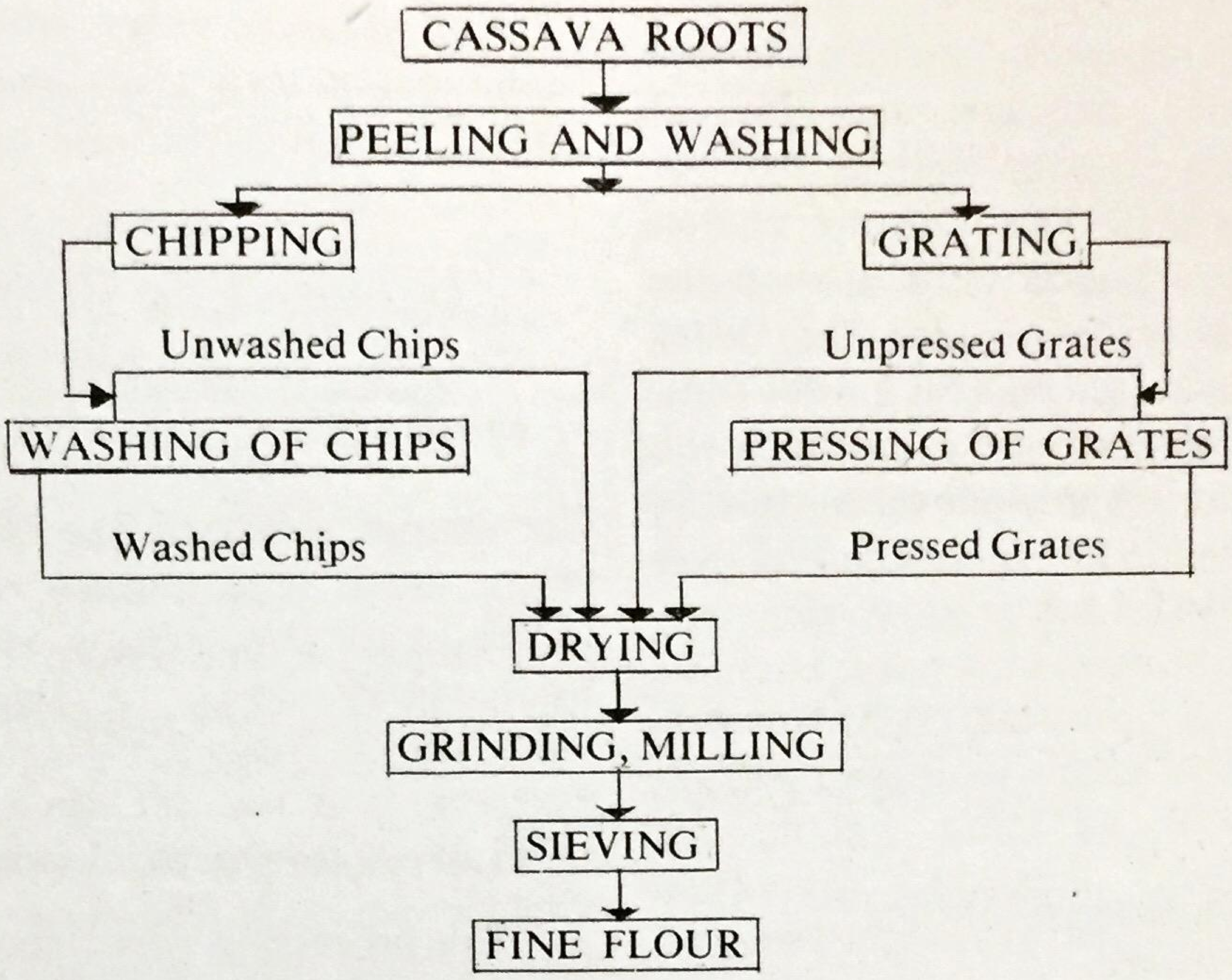

Figure 1. Flow diagram of cassava flour production using different primary processing techniques.

$$\text{Initial M.C.w.b. (\%)} = \frac{\text{Initial wt.} - \text{Bone-dry wt.}}{\text{Initial wt.}} \times 100$$

where Bone-dry wt. = Weight of the sample after oven-drying at which the moisture level is 0.

All treatments were sun-dried at 1-cm drying depth. The drying process was closely monitored by weighing the different treatments using a digital balance at hourly interval until 10-12% M.C.w.b. ($\approx$11-14% M.C.d.b.) was reached in each treatment. This moisture level was used because it is ideal for easy grinding process and longer storage life of flour and chips (Weber et al., 1978). The final moisture content was determined using the following equation:

$$\text{Final M.C.w.b. (\%)} = 100 - \frac{\text{Initial wt.}}{\text{Final wt.}} (100 - \text{Initial M.C.w.b.})$$

The drying curve of each treatment was analyzed using exponential regression analysis through computer package and through the least squares method by Walpole (1974). The moisture content (dry basis) data were used in this analysis to emphasize the difference in water content of the flour treatments when comparing drying behavior. The following equation was used in converting % M.C.w.b. to % M.C.d.b.):

$$\%\ \text{M.C.d.b.} = \frac{100\ (\%\ \text{M.C.w.b.})}{100 - (\%\ \text{M.C.w.b.})}$$

Determination of Milling Performance

The dried chips and grates were milled once using the PRCRTC pedal-operated hammer mill type of grinder. The milled chips/grates were made to pass through mesh number 60 sieve to separate the desired fine flour. The milling rate of crude flour, milling efficiency of fine flour and production rate of refined flour were determined using the following equations:

Determination of Flour Recovery

The flour recovery from raw/unpeeled cassava roots was determined using the following equation:

$$\text{Flour recovery}\ (\%) = \frac{\text{Output}}{\text{Input}} \times 100$$

where:

Output = Wt. of fine flour produced

Input = Initial wt. of raw root materials

Cost Accounting of Processing

The processing cost (labor plus maintenance cost) of each technique from root preparation to flour milling was computed using the current labor rate of ₱3.75/hr. According to Henderson and Perry (1976), maintenance cost is frequently valued at an average of 3% of machine cost per year. Thus; assuming an 8-hr work per operation, one operation per week, and 52 weeks per year, the maintenance cost per hour was determined using

$$\text{Milling rate (kg/hr)} = \frac{\text{Wt. of crude flour (kg)}}{\text{Milling time (hr)}}$$

$$\text{Milling efficiency}\ (\%)\ \frac{\text{Wt. of fine flour}}{\text{Wt. of dried chips/grates}} \times 100$$

$$\text{Production rate (kg/hr)} = \frac{\text{Milling rate} \times \text{Milling efficiency}}{100}$$

the following equation:

$$\text{Maintenance cost/hr} = \frac{3\% \text{ of machine cost (₱)}}{8 \times 1 \times 52 \text{ (hr)}}$$

RESULTS AND DISCUSSION

Effects on Chipping/Grating Capacity

Chipping capacity is generally greater (about three times more) than the grating capacity as shown in Table 1. Thus, chipping of cassava roots is more efficient than grating as far as size reduction efficiency is concerned. At ₱3.75/hr labor rate and ₱0.18/hr maintenance cost, chipping and grating cost ₱11.95 and ₱33.90 per ton, respectively.

Effects on Drying Characteristics

The drying behavior of the different preparations of sundried cassava roots is shown in Figure 2. The exponential regression equations which were obtained from the moisture contents (dry basis) of chips/grates throughout the drying time, represent the drying curves of the different root preparations under ideal/natural drying operation. Moisture reduction proceeded rapidly at the initial stage of drying and slowed down as it reached the desired moisture level (11-14% d.b.). The pressed grates showed the shortest drying time of only 8 hours, whereas the washed chips and the unpressed grates took the longest time to dry, i.e. 18 and 17 hours, respectively. This could be attributed to the wide difference in their initial moisture contents as reflected in Table 2. Washing the chips increased the moisture level by 40.16% which consequently delayed the drying time by 3 hours. Manually pressing the rasped roots or grates using a mechanical presser reduced the moisture level by 48.28% which in effect shortened the drying time by 9 hours. However, additional labor was required in pressing the grates.

Effects on Milling Performance

Using a pedal-operated hammer mill type of grinder, dried cassava grates were ground faster than dried cassava chips as shown in Table 3. However, grates had considerably low milling efficiency with only 20-21% fine flour. Thus, the remaining 80% crude flour needs regrinding. The dried chips though requiring longer milling time, produced a higher proportion of fine flour of about 53-54%.

The effective rate of refined flour production can be gauged by the amount of fine flour produced per unit time. Chips generally had higher milling efficiency with refined flour production rate ranging from 4.41-4.83 kg/hr (Table 4). The effective flour production rate of grates ranged only from 2.82 to 2.98 kg/hr. These results indicate

Table 1. Capacities of the operations involved in the different root processing techniques before drying.[1]

Treatment	Root Peeling, Manual (kg/hr)	Root Washing, Manual (kg/hr)	Chipping/ Grating, Pedal Chipper/ Grater (kg/hr)	Chip Washing/ Manual Grate Pressing Using Mechanical Presser (kg/hr)
Chipping without washing	29	121.50	329	—
Chipping and washing	29	121.50	329	90
Grating without pressing	29	121.50	116	—
Grating and pressing	29	121.50	116	46

[1] Based on one-man labor

that chips have better milling performance than grates.

Over-all Performance of Flour Production

Flour production can be expressed in terms of processing time per ton of roots into refined flour. As shown in Table 4, processing time of root chips into flour ranged from 267.79 to 301.62 hr/ton, whereas that of grates ranged from 403.90 to 435.68 hr/ton. Thus, processing of chips into flour is faster than that of grates. Furthermore, a remarkable difference in the flour recovery (percentage of flour produced from a certain amount of root material) of the chips and grates can be observed (Table 4). Flour recovery (clean and refined flour) of chipped roots ranged from 25 to 29% while that of grated roots ranged only from 9 to 11%. This could partly be explained by the fact that processing flour by grating causes great loss of soluble starch substances, especially when the grates are pressed. Another factor is the milling behavior of the grates in the hammer mill. Since the grates consist largely of fibers and coarse particles, their breaking impact on finer particles is less. As a result, most of the coarse flour passes through the screen apertures unpulverized and most of the fibers are retained in the screen. In contrast, the breaking impact of chips on finer particles is greater, causing them to shatter and resulting in the production of still finer particles. Moreover, the fibers in the chips can be ground into still finer ones.

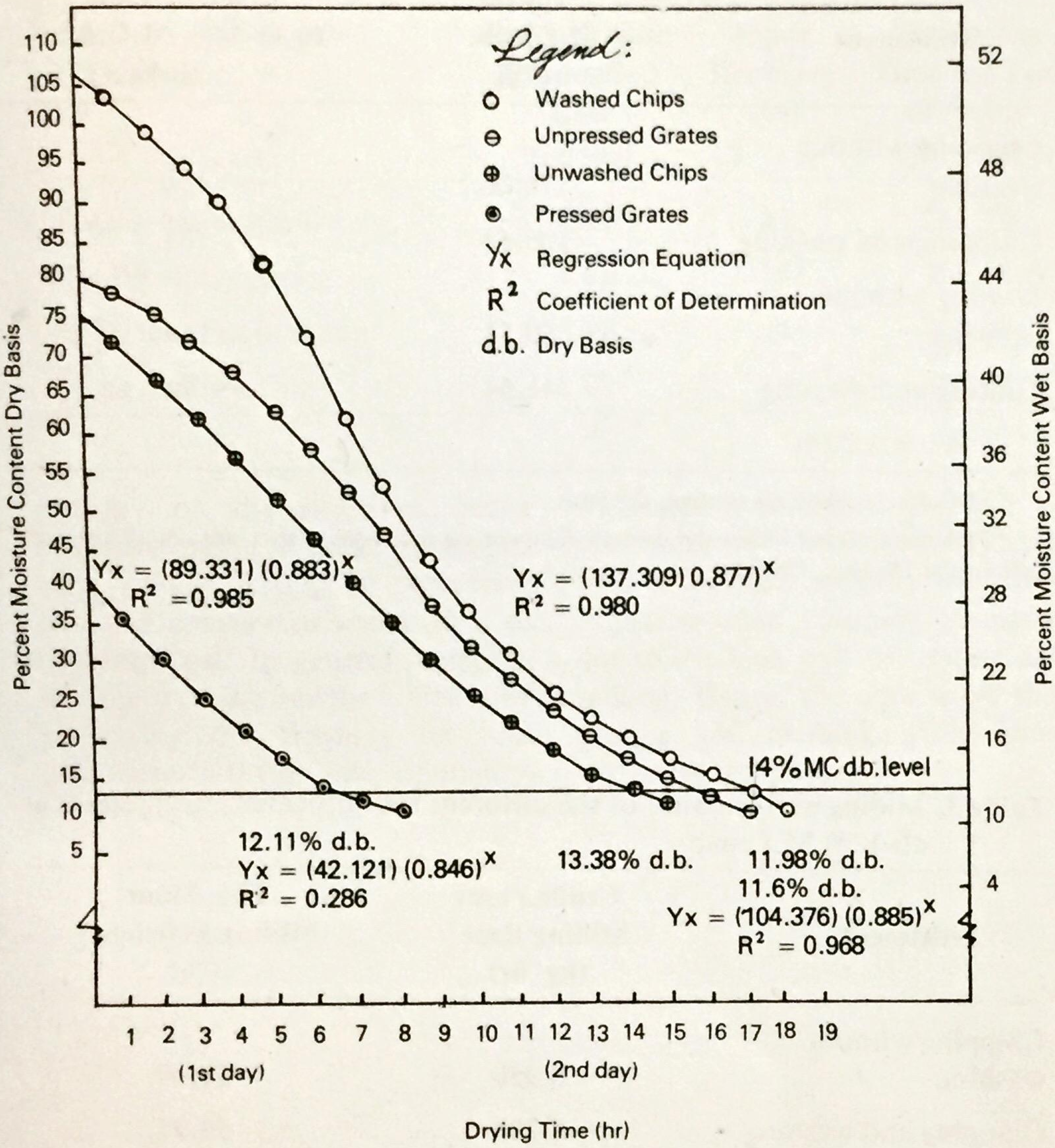

Figure 2. Drying behavior of different preparations of sundried cassava roots.

Cost Accounting of Flour Production

The processing costs of the different operations involved in flour production are summarized in Table 5. It can be noted that the most expensive processing operation is milling, constituting about 80% of the total cost. It ranged from ₱813.70/ton to ₱1,393.60/ton. This could be attributed to the low

Table 2. Drying performance of the different root processing techniques.

Treatment	Initial M.C.d.b.[1] (%)	Drying Time to 11-14% M.C.d.b.[2] (hr)
Chipping without washing	76.06	15b
Chipping and washing	106.61	18a
Grating without pressing	80.51	17ab
Grating and pressing	41.64	8c
C.V. = 1.72%		

[1]M.C.d.b. = Moisture content, dry basis

[2]Treatment means within the column followed by a common letter are not significantly different at 1% level, DMRT.

Table 3. Milling performance of the different root processing techniques at 10-12% M.C.w.b.

Treatment	Crude Flour Milling Rate[1] (kg/hr)	Fine Flour Milling Efficiency (%)
Chipping without washing	8.95b	54.00
Chipping and washing	8.20b	53.72
Grating without pressing	14.05a	21.20
Grating and pressing	13.70a	20.60
C.V. = 6.0%		

[1]Treatment means within the column followed by a common letter are not significantly different at 1% level, DMRT.

Table 4. Flour production performance of the different root processing techniques.

Treatment	Refined Flour Production Rate (kg/hr)	Flour Recovery (%)	Processing Time per Ton of Roots (hr/ton)
Chipping without washing	4.83	29	267.79
Chipping and washing	4.41	25	301.62
Grating without pressing	2.98	11	403.90
Grating and pressing	2.82	9	435.68

capacity of the machine, being manually operated only. Peeling of roots ranked second in processing cost and constituted about 10% of the total cost. In general, chipping without washing had the lowest total processing cost. Washing the chips is probably a better practice quality-wise, but it increased the cost of processing by ₱131.85/ton. Grating with or without pressing was more expensive than chipping primarily due to the high cost of grating and milling. Hence, the data show that grating and pressing is the most expensive technique.

Table 5. Processing cost of operations involved in the different processing techniques of cassava flour production.

Treatment	Root Peeling (₱/ton)	Root Washing (₱/ton)	Chipping/ Grating (₱/ton)	Chip Washing/ Grate Pressing (₱/ton)	Drying Operation (₱/ton)	Milling Operation (₱/ton)	Total Processing Cost (₱/ton)	Total Processing Cost (₱/kg)
Chipping without washing	129.30	30.90	11.95	—	56.25	813.70	1042.10	1.04
Chipping and washing	129.30	30.90	11.95	43.10	67.50	891.20	1173.95	1.17
Grating without pressing	129.30	30.90	33.90	—	63.75	1318.80	1576.65	1.58
Grating and pressing	129.30	30.90	33.90	84.35	30.00	1393.60	1702.05	1.70

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